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SHORT COMMUNICATION

COLOR DIMORPHISM IN ADULTS AND JUVENILES OF *BUITINGA SAFURA* (ARANEAE, PHOLCIDAE)

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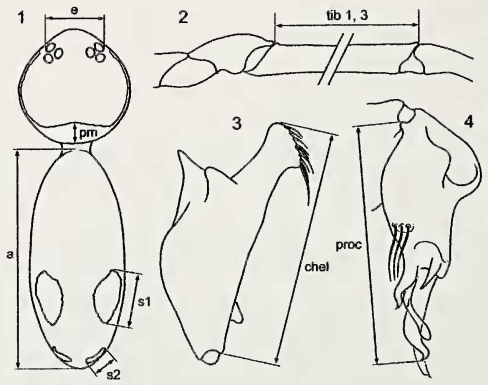
ABSTRACT. We document the first case of a color dimorphism in a pholcid spider. Males, females and juveniles of *Buitinga safura* Huber 2003 either have large black spots on the abdomen or no spots, with no intermediates. At the same time, this species shows sexual dimorphism (brown prosomal marks present in males only) and continuous prosomal pattern variation in males, females and juveniles. The abdominal pigment is located in the hypodermis.

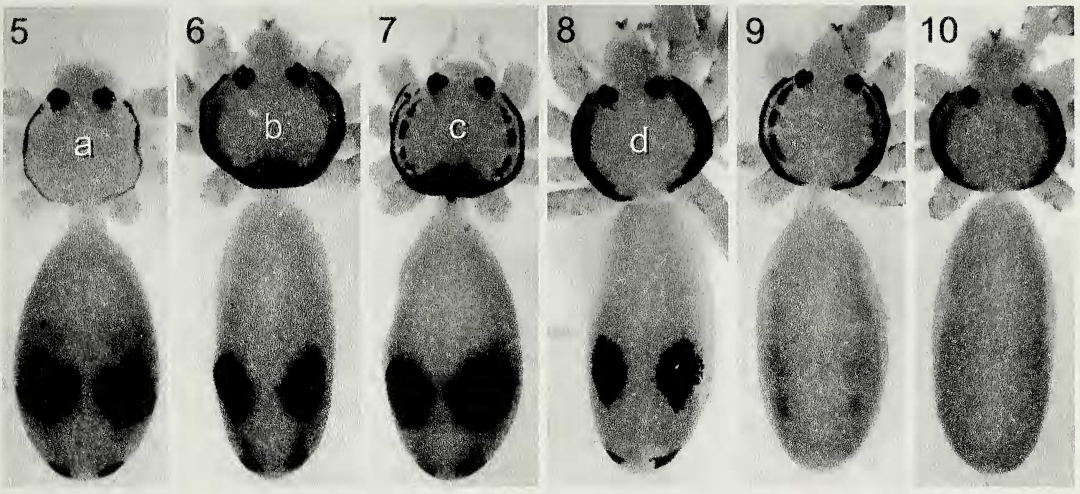
Keywords: Color dimorphism, polymorphism, pattern variation, Pholcidae

Intrasexual polymorphism (discontinuous individual variation among members of the same sex, in the same life stage, within a population) is considered a key phenomenon for the study of basic evolutionary concepts (e.g., West-Eberhard 1989; Gould 1989; Eberhard & Gutierrez 1991; Mayr & Ashlock 1991; Emlen 1994). Color polymorphisms, being easily visible, are among the best studied and considerable progress has been made introducing spiders as possible model arthropods with which to study the evolutionary processes working on visible, intraspecific variation. Spectacular examples include the candy-striped spider, *Enoplognatha ovata* (Clerck), and the Hawaiian happy-face spider, *Theridion grallator* Simon, but many cases have been described in various spider families. Extensive reviews on spider coloration and polymorphism have been published recently by Oxford & Gillespie (1998) and Oxford (1999).

We present here the first case of a color polymorphism in the spider family Pholcidae. A large series of *Buitinga safura* Huber 2003 was collected in the Uzungwa Mountains, Iringa Province, Tanzania (for details of study site, see Sørensen et al. 2002), by an expedition of the Smithsonian Institution in Washington, D.C. and the Zoological Museum of Copenhagen in May 1997. The material studied herein is deposited in the National Museum of Natural History (Washington, D.C., U.S.A.). Specimens were collected from litter and logs, low vegetation, understory and canopy, and transferred to 70% ethanol (Sørensen et al. 2002). The present analysis is restricted to the largest subsample, i.e. to the 1139 specimens collected from the understory, but inspection of the other material suggests that the patterns described below do not differ significantly among habitats. We measured nine traits (Figs. 1–4) with a measuring grid in the ocular of a Nikon SMZ-U dissecting microscope and assessed prosomal pattern variation in a qualitative way (Figs. 5–8). Tables 1 and 2 give the sample sizes, means, ranges, standard deviations, coefficients of variation, significance values of Kolmogorov-Smirnov tests for normal distribution and estimates of measurement error for all measured traits.



Figures 1–4.—Illustrations of characters measured. 1. Prosoma and abdomen, dorsal view; a = abdomen length, e = eye distance, pm = posterior mark on carapace, s1, s2 = abdominal spot 1 and 2 lengths. 2. Tibia, lateral view; tib 1,3 = tibia 1 and tibia 3 lengths. 3. Right male chelicera, lateral view; chel: chelicera length. 4. Left procursus, prolateral view; proc = procursus length.



Figures 5–10.—Photographs of six adult *Buitinga safura* specimens showing some of the color variation described: abdominal spots present (5–8) vs. absent (9–10), posterior mark on carapace present (6–7) vs. absent (5, 8–10), brown bands on carapace present (6, 8, 10) vs. absent (5, 7, 9), and the four arbitrarily defined degrees of lateral prosomal patterns: a (only black lines), b (black lines plus brown bands), c (black lines plus three pairs of black spots), d (black lines plus brown bands plus three pairs of black spots).

From 341 adult males in the sample, 20 had two pairs of spots on the abdomen, two had only one (the posterior) pair of spots. These 22 spotted males were all measured. From the remaining 319 spotless males, 23 were randomly selected and included in the quantitative analysis, resulting in a total of 45 males measured. Histograms of male spot lengths clearly indicate that these are not cases of continuous variation (Figs. 11, 12). All other traits measured (with the exception of the posterior mark on the carapace, see below) show unimodal distributions that are not significantly different from normal distributions (Table 1). All specimens are considered conspecific because those characters that in pholcids differ most among species (procursus, bulb, cheliceral armature; see Huber 2003) were virtually identical. From a scatter between two characters with high interspecific variation (procursus, chelicerae), it is evident that spotted (o) and spotless (+) males occur at any sizes of these characters (Fig. 13). Also, there was no correlation between overall size and abdominal pattern (Fig. 14; t-test calculated for tibia 1 length, tibia 3 length, and eye distance: all $P > 0.05$). Ordinary least squares (OLS) regressions of log-transformed characters were calculated for all traits on eye distance as an indicator of body size (for justification of method see Eberhard et al. 1999). As in the comparative study by Eberhard et al. (1998), legs and other non-genitalia had relatively high slopes (tibia 1 length

Table 1.—Male characters measured, with sample sizes (n), means, ranges, standard deviations (SD), coefficients of variation (CV), significance values of Kolmogorov-Smirnov tests for normal distribution (KS), and estimates on measurement error.

Character	n	Mean (mm)	Range (mm)	SD	CV	KS	Measurement error (± mm)
Tibia 1 length	39	5.65	5.00–6.13	0.286	5.1	0.81	0.07
Tibia 3 length	44	2.48	2.20–2.73	0.109	4.4	0.47	0.03
Abdomen length	45	1.90	1.58–2.25	0.166	8.7	0.24	0.03
Eye distance	44	0.56	0.52–0.60	0.018	3.2	0.21	0.01
Chelicera length	44	0.60	0.53–0.63	0.024	4.2	0.62	0.01
Procursus length	43	0.53	0.51–0.56	0.012	2.4	0.48	0.01
Abdominal spot 1	20	0.48	0.38–0.60	0.061	12.7	0.00	0.03
Abdominal spot 2	22	0.24	0.15–0.35	0.042	17.4	0.00	0.03
Carapace posterior mark	7	0.26	0.05–0.38	0.117	44.3	0.00	0.03

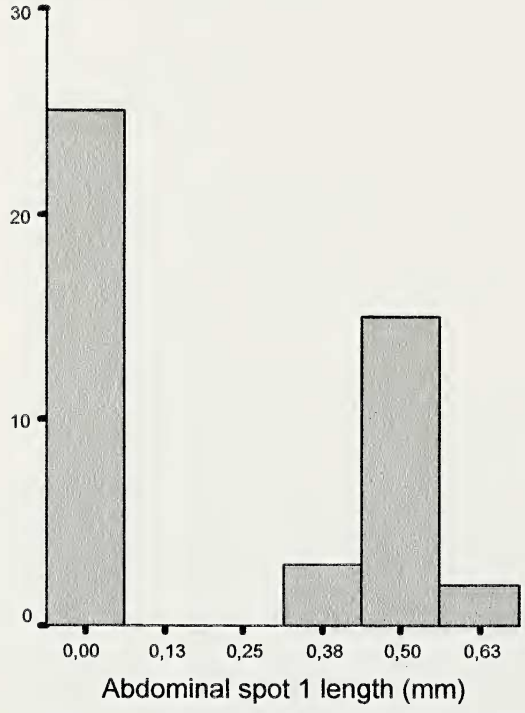
Table 2.—Female characters measured, with sample sizes (n), means, ranges, standard deviations (SD), coefficients of variation (CV), significance values of Kolmogorov-Smirnov tests for normal distribution (KS), and estimates on measurement error.

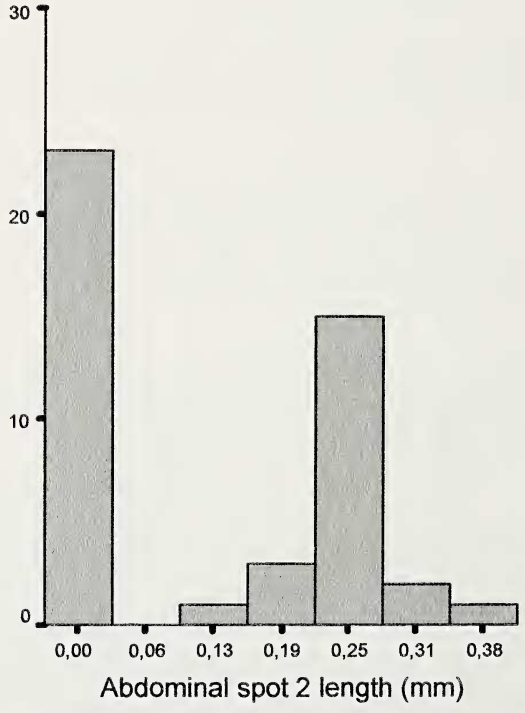
Character	n	Mean (mm)	Range (mm)	SD	CV	KS	Measurement error (± mm)
Tibia 1 length	50	4.75	4.37–5.23	0.196	4.1	0.70	0.07
Tibia 3 length	54	1.98	1.87–2.17	0.070	3.5	0.19	0.03
Abdomen length	56	1.75	1.38–2.18	0.157	9.0	0.87	0.03
Abdominal spot 1	29	0.49	0.35–0.73	0.084	17.3	0.00	0.03
Abdominal spot 2	31	0.21	0.13–0.28	0.037	17.7	0.00	0.03
Carapace posterior mark	4	0.20	0.13–0.28	0.061	30.6	0.00	0.03

= 1.00; tibia 3 length = 0.79; chelicerae length = 0.73; all $P < 0.001$), while procursus length had a much lower slope (0.38; $P < 0.001$), as is usual for genitalia. This trend remained when spotted and unspotted individuals were analyzed separately, but there was considerable variation among slopes of spotted vs. unspotted males (probably due to small sizes of subsamples). The slope of abdomen length on eye distance was non-significant.

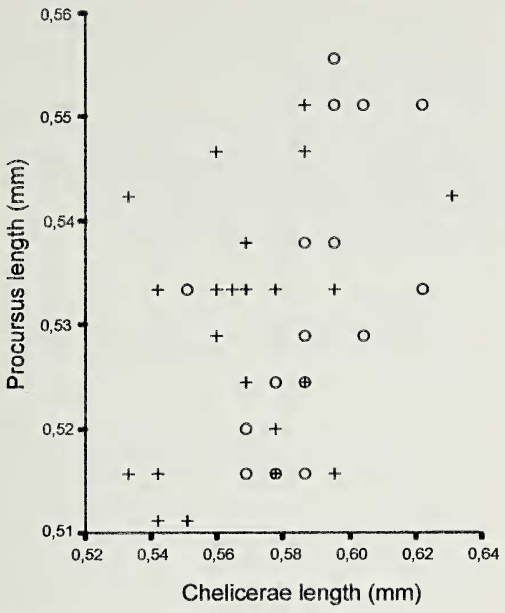
Male prosomal pattern variation was also substantial. However, this variation was continuous and not dimorphic. We arbitrarily defined four types within the continuum of lateral prosomal patterns (Figs. 5–8), but found no significant correlation of these with body size (Fig. 15) or abdominal pattern (Fig. 16). In seven (out of 341) males, there was a large black mark posteriorly on the carapace (Fig. 6). This trait may be dimorphic too, but sample size is obviously too small. All of these males also had abdominal spots, but two of them had only the posterior pair.

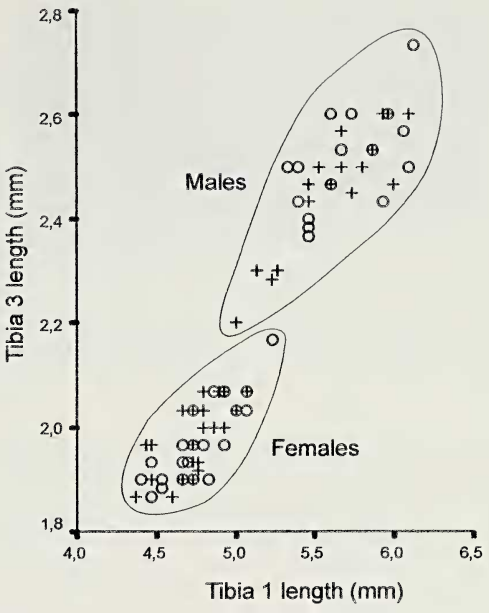
In females we measured the same traits except for eye distance, procursus length and chelicera length. From the 385 adult females in the sample, 29 had both pairs of abdominal spots, two had only one (the posterior) pair, all others were spotless.



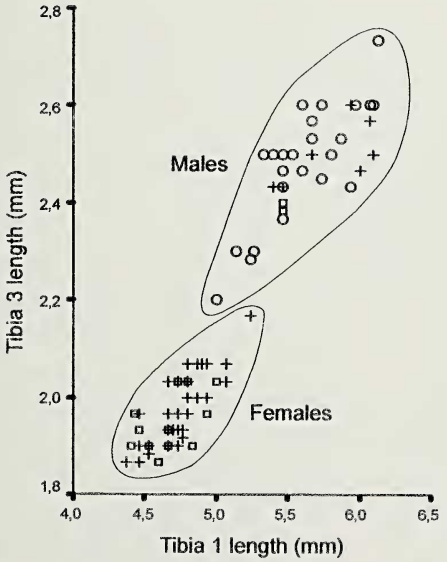


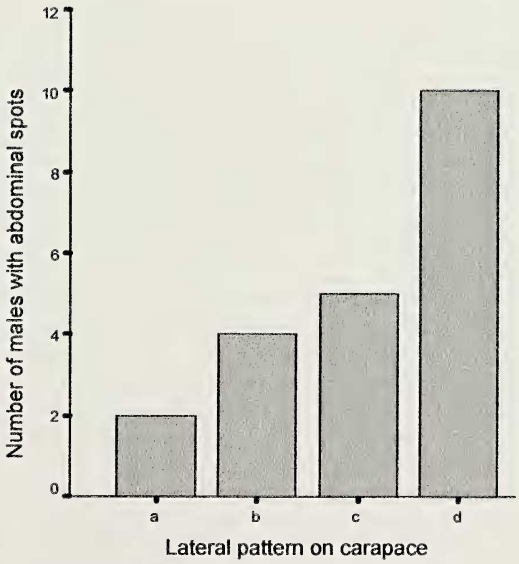
Figures 11, 12.—Histograms showing the bimodal distributions of abdominal spot sizes in males. Note that the left bars indicating spotless specimens represent only a small fraction of the more than 300 spotless males in the original sample.





Figures 13, 14.—Scatter diagrams showing the presence or absence of abdominal spots (o = spotted, + = spotless) in males with different sizes of chelicerae and procursi (13) and in males and females of different overall size as indicated by leg length (14). Fig. 13 strongly supports conspecificity of spotted and spotless males, while Fig. 14 shows that there is no correlation between abdominal spottedness and size.





Figures 15, 16.—15. Scatter diagram showing the distribution of lateral prosomal patterns in males and females of different sizes: pattern "a" (Fig. 5; represented by squares) occurs in males and females but is rare in males; patterns "b" and "d" (Figs. 6 and 8; represented by circles) occur only in males; pattern "c" (Fig. 7; represented by crosses) occurs in both sexes. 16. Bar diagram showing that abdominal spots occur in males with all different kinds of prosomal patterns. Sample size is too small to judge the significance of the increase in cases of abdominal spots from a–d.

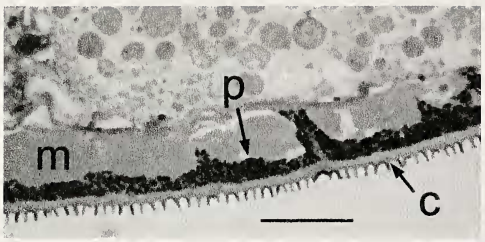


Figure 17.—Semithin section of a female abdomen in the area of a spot, showing the location of the pigment in the hypodermis; c = cuticle, m = subcuticular muscle layer, p = pigment. Scale line: 25μm.

From these, 25 randomly chosen individuals were measured resulting in a total of 56 measured females. Abdominal spot sizes in females were similar to those in males (see Tables 1 and 2) and the proportions of spotted vs. unspotted specimens was not significantly different in males vs. females (chi square = 0.684, $P = 0.408$, 1 df). However, females never had brown marks on the prosoma, i.e. they showed only two of the four lateral prosomal patterns shown in Figs. 5–8. Therefore, in addition to the abdominal intrasexual dimorphism there is also an (inter)sexual dimorphism. Posterior black marks occurred in four females and all of these also had abdominal spots, but two of them only the posterior pair. The epigyna of all females were indistinguishable.

In juveniles we only counted the numbers of spotted and spotless specimens (19 vs. 394). The percentage of spotted individuals was similar to that in adults (chi square = 4.022, $P = 0.134$, 1 df). Most juveniles were late or penultimate instars. Prosomal pattern variation in juveniles appeared similar to that in females, but most juveniles had only the black lines (cf. Fig. 5) and lateral spots, if present, were usually very weak. Posterior black marks on the carapace were not seen in juveniles.

The abdominal pigment is located in the hypodermis: removal of the digestive tract left the spots intact, but after treatment with NaOH they could be removed easily from the cuticle using a brush. This result was confirmed by preparation of semithin sections (Fig. 17). By comparison with other spider pigments (Oxford & Gillespie 1998), the location suggests it is an ommochrome. There is no evidence that preservation in ethanol has had any effect on the abdominal spots: they are either deep black or entirely absent. Little can be said beyond these basic facts. The truly interesting questions remain to be answered: is the polymorphism genetically determined? Is it selectively maintained, and if yes, by which selective forces? What are the costs of producing spots, if any? How many alleles contribute to the polymorphism, and which morph is dominant?

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